

The impacts of ROMEX data on Spire's Operational Deterministic Global Forecasts



weather & climate

Kristen Bathmann, Dusanka Zupanski, Tom Gowan, Mathew Rothstein

Spire Global Inc., Boulder CO USA
 Kristen.Bathmann@spire.com
 IROWG-10 2024

Abstract

Spire Global operates a constellation of over 100 satellites, capable of measuring up to 10,000 radio occultation (RO) profiles per day. Leveraging its proprietary data, Spire provides global and regional weather forecasting services. To understand how RO enhances Numerical Weather Prediction (NWP), Spire plans to run a ROMEX experiment, which will assimilate 35,000 RO profiles per day.

A previous RO data denial study performed by Spire showed that the assimilation of 10,000 Spire RO profiles per day into the global Spire Operational Forecast-Deterministic (SOFD) resulted in an increase in forecast skill at extended forecast lead-times, with greatest impacts further away from the equator. Through comparison with this data denial experiment it will be possible to understand how assimilating increasing amounts of RO impacts NWP, and if data saturation occurs.

Spire Operational Forecast-Deterministic

Spire runs a global forecasting model, SOFD, with the goal of using proprietary data and techniques to generate forecasts that meet customer needs:

- GSI/UFS based with 4DVar and custom treatment of RO
- Cold start from ECMWF background, 50 ensemble members
- Conventional observations, radiance, ozone, RO, and satellite winds assimilated
- 15 Day forecasts initialized at 0Z, 12Z

Previous Studies with SOFD and Spire RO

Spire conducted a Spire RO data denial study for 1 Sep - 23 Nov 2021:

- **SOFD** Operational global model run, initiated using all available observations, including Spire RO observations
- **SOFDNoSpireRO** Spire RO data denial experiment, the same as SOFD, but without Spire RO data

Spire	2502 per cycle	Spire/Total = 55.4%
COSMIC-2	1377 per cycle	COSMIC-2/Total = 30.5%
MetOp	561 per cycle	MetOp/Total = 12.4%
KOMPSAT-5	46 per cycle	KOMPSAT-5/Total = 1.0%
TerraSAR-X	27 per cycle	TerraSAR-X/Total = 0.6%
Total	4513 per cycle 18K per day	100%

Table 1: RO profile counts per analysis cycle (initialized at 0Z, 6Z, 12Z, 18Z) in the SOFD Experiment. The SOFD-NoSpireRO does not use Spire data from row 1. The counts account for data latency at the operational run time.

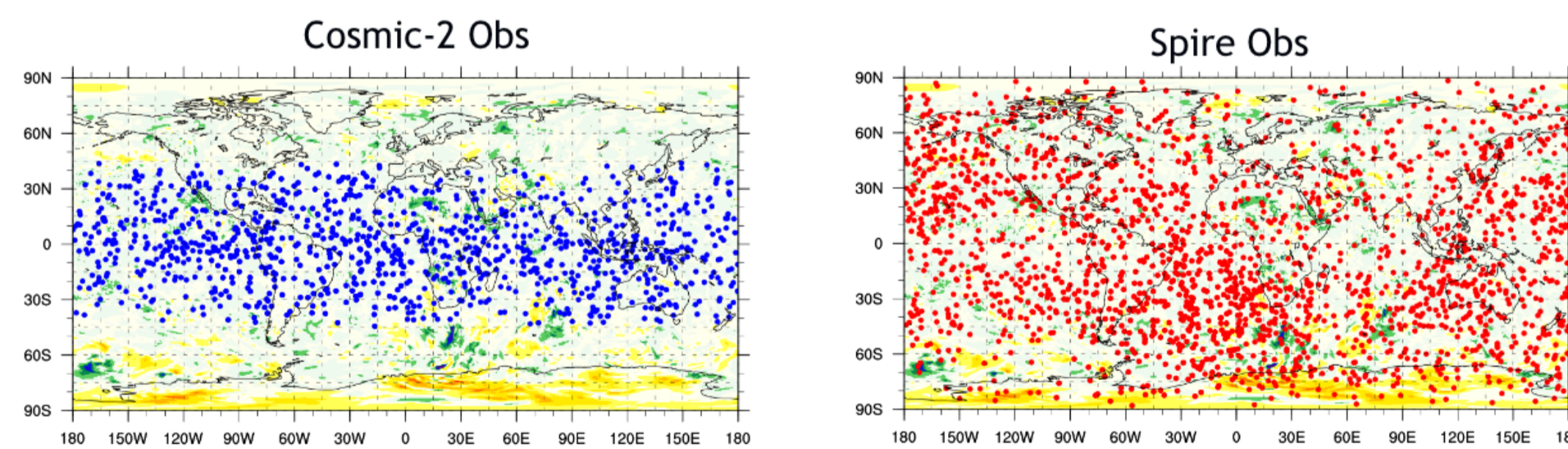


Figure 1: The locations of COSMIC-2 (left) and Spire (right) observations for the 00z Sep 5, 2021 cycle.

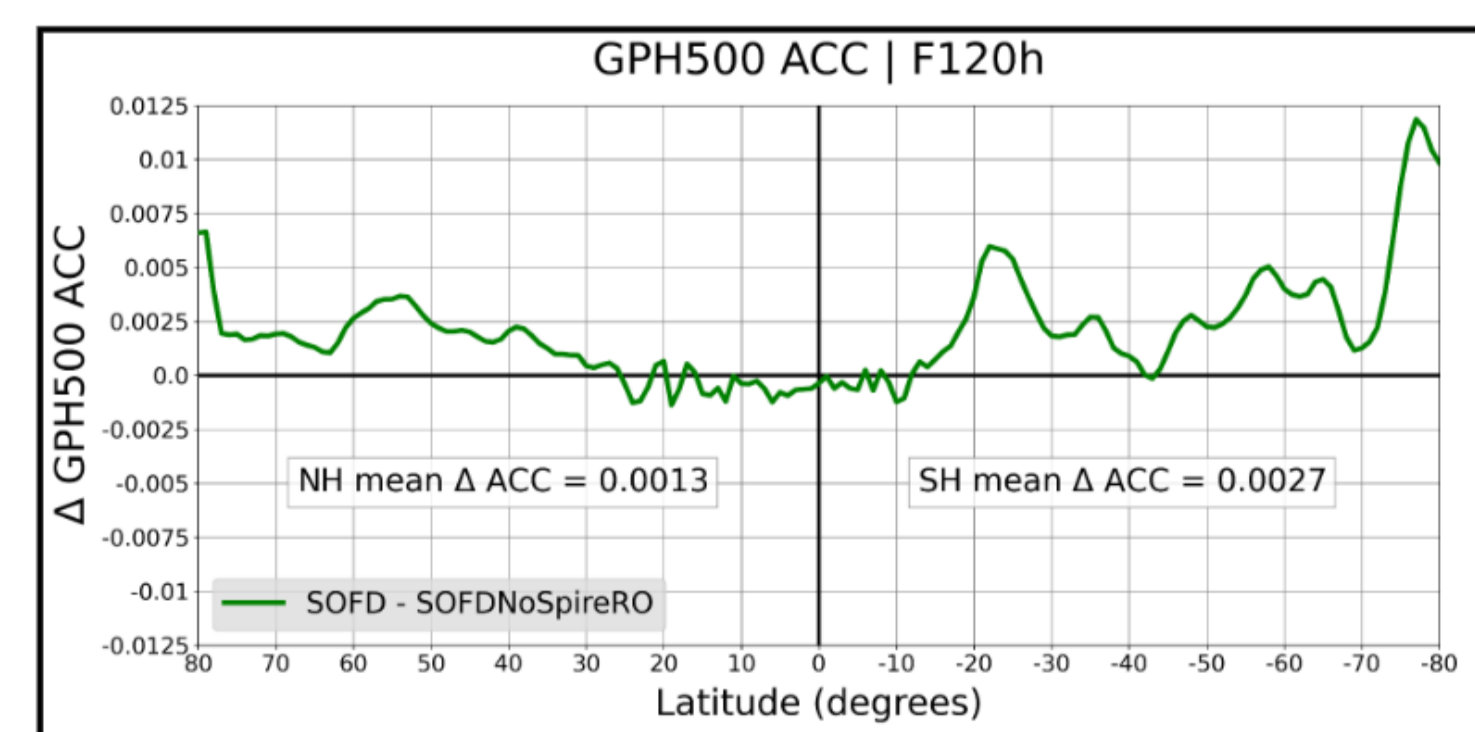


Figure 2: The mean difference in 5-day 500hPa Anomaly Correlation Coefficient (ACC) between SOFD and SOFD-NoSpireRO (SOFD - SOFDNoSpireRO) as a function of latitude during the entire experiment. Positive difference in ACC indicates improvement in SOFD over SOFDNoSpireRO. ECMWF analyses are used as truth in verification.

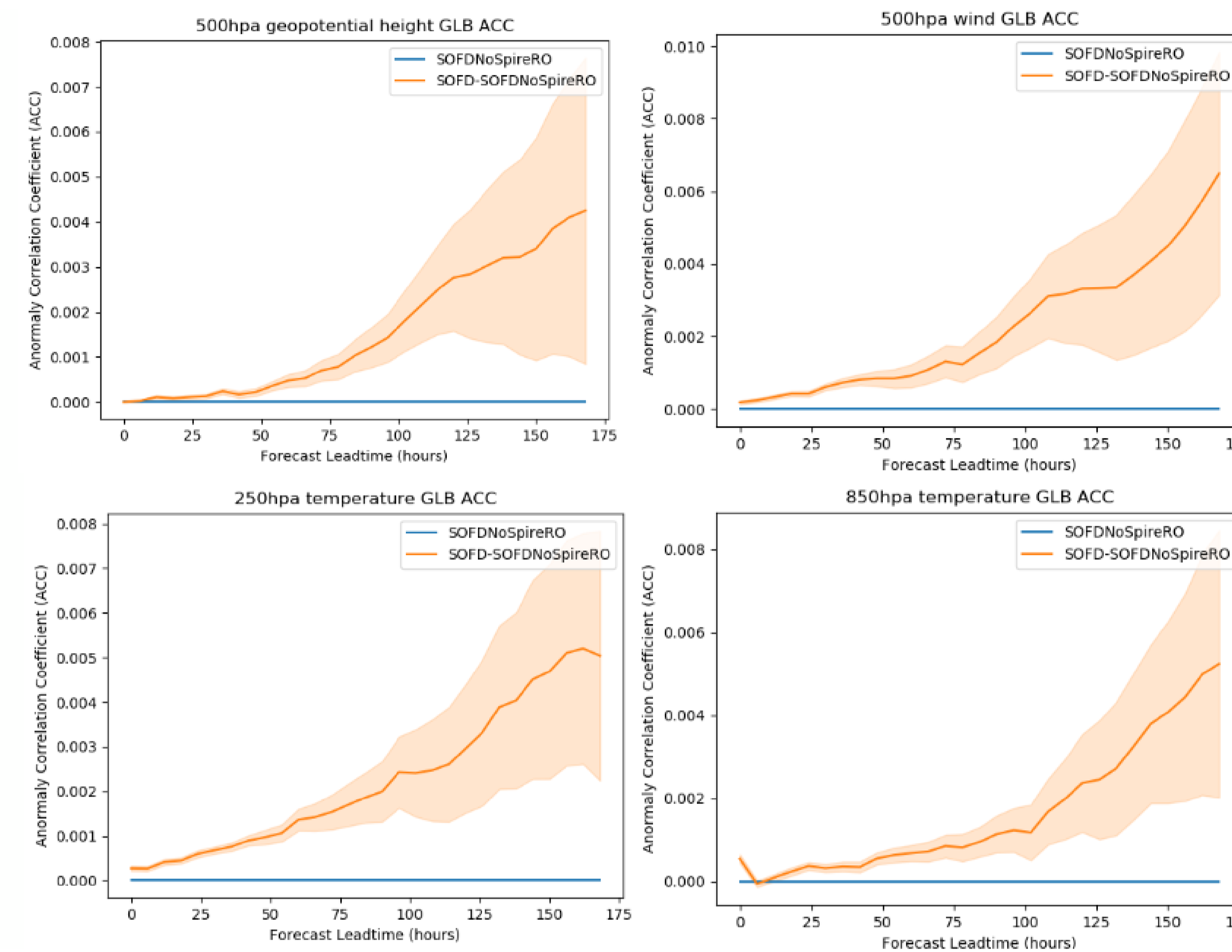


Figure 3: The mean difference between SOFD and SOFDNoSpireRO (SOFD - SOFDNoSpireRO) in geopotential height, wind, and temperature ACC at different levels of the atmosphere, globally averaged over the 3 month experimental period, versus forecast lead-time. ECMWF analyses were used as truth in verification. Shading indicates 95% confidence intervals.

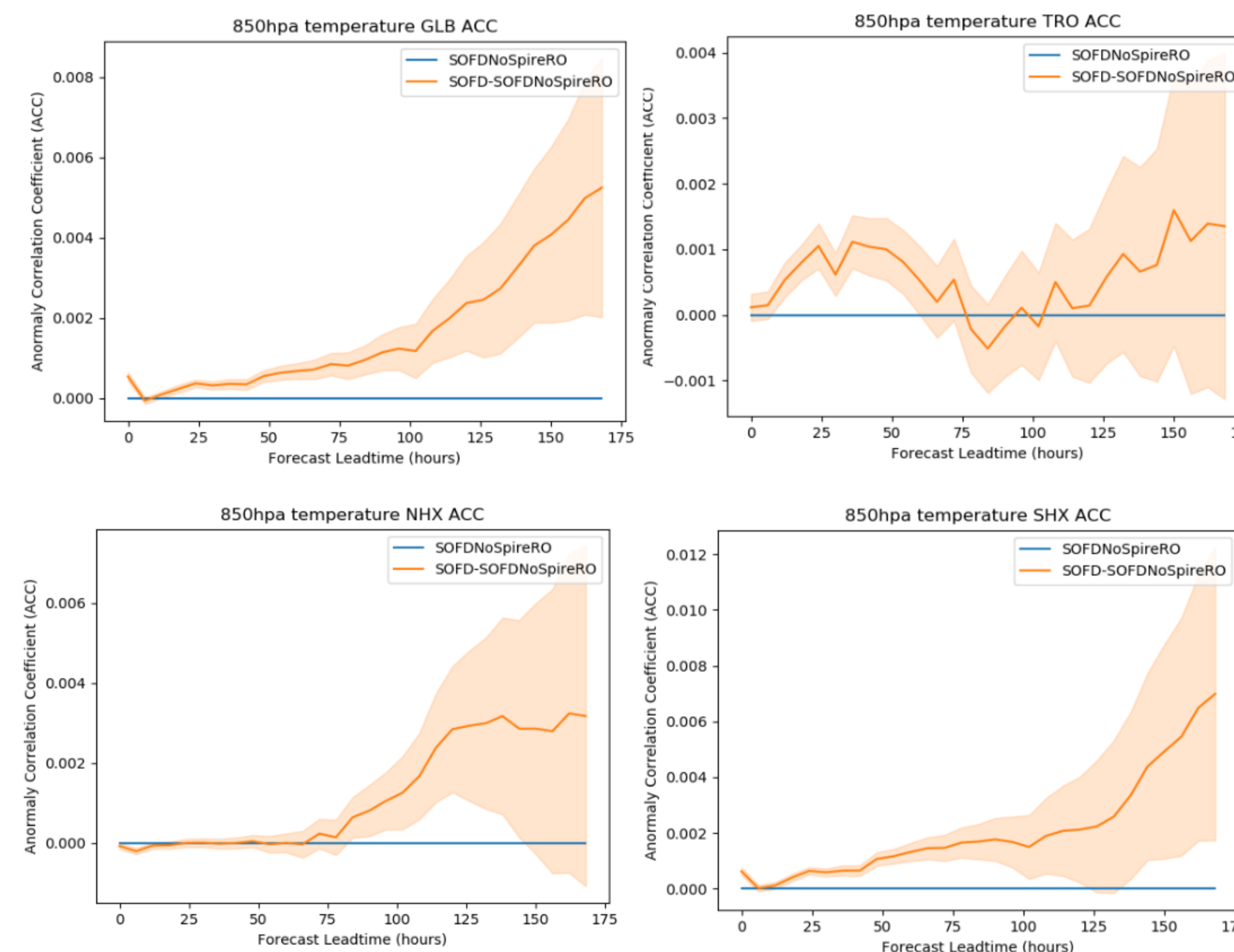


Figure 4: As previous figure, but for temperature at 850hpa globally averaged, and averaged over the tropics, northern hemisphere and southern hemisphere.

Various verification metrics in Figs. 3-4 show the positive impacts of assimilating 10,000 Spire RO profiles per day

- Values above blue lines in Figs. 3-4 indicate higher ACC in the SOFD experiment, and therefore a positive impact of Spire RO observations
- Other verification metrics were examined and found to show similar results (not shown)

Positive impacts shown in Figs. 2 and 4 are greater in southern hemisphere, and greater further away from tropics:

- RO likely compensates for a lack of in situ observations in southern hemisphere
- COSMIC-2 observations are concentrated in tropics, Spire observations are more evenly distributed across the globe
- Spire RO is more impactful over regions without COSMIC-2 data

Data Denial Study Summary

The ACC differences demonstrate, with 95% confidence, SOFD forecast improvements due to assimilation of Spire RO data:

- Globally, in the tropics, northern hemisphere extratropics and southern hemisphere extratropics (with the exception that, in the tropics, the results are not always significant at 95% level of confidence)
- For all forecast lead times 0h -168h
- For standard atmospheric variables (geopotential height, temperature and wind)
- For standard vertical levels (250 hPa, 500 hPa, 700 hPa, 850 hPa and 1000 hPa)
- There is good evidence that RO improves forecasts most over poorly observed regions

Plans for ROMEX

Spire's ROMEX experiment will expand on the results of the data denial experiment by doubling the amount of assimilated RO.

The experiment will use an upgraded version of SOFD as compared to the data denial study, run at lower resolution, and update the **SOFD RO assimilation algorithm**:

- A recent upgrade to SOFD updated the RO observations errors and added the ability to account for vertical error correlations in RO profiles.
- Spire internal RO processing produces profiles at very high vertical resolution (200m), and introduces strong vertical error correlations.

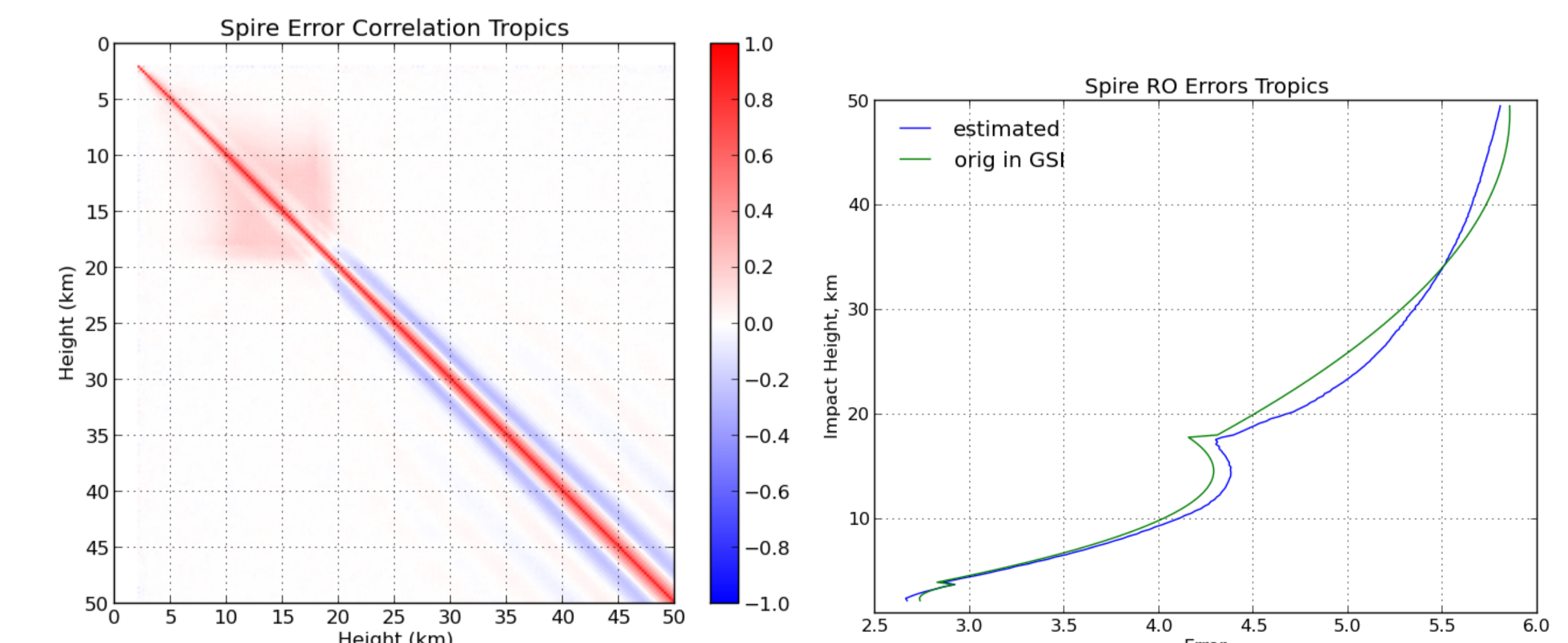


Figure 5: Estimated correlations and errors for Spire RO. Errors shown are actually - log(err), so as values in the plot increase, actual errors decrease.